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Radiation Fields, Effects and Risks in Human Space Missions (5)

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INFLUENCE OF LUNAR CRATER TOPOGRAPHY AND SHIELDING ON RADIATION EXPOSURE IN LUNAR HABITATS

Abstract

As human exploration advances toward sustained lunar surface missions, mitigating exposure to galactic cosmic ray (GCR) and solar energetic particles (SEP) remains a critical challenge for astronaut health and mission planning. While lunar crater topography provides some natural geometric shielding by reducing incident particle flux, the combined effects of topographic placement and engineered structural shielding require further investigation. This study extends previous analyses of crater-based habitat placement by incorporating additional shielding materials surrounding a lunar habitat. Monte Carlo simulations were performed using the PHITS MC radiation transport code to model habitats on flat terrain and within craters of varying depths, with structural shielding layers composed of candidate materials introduced to evaluate their impact on effective dose equivalent under solar minimum and solar maximum conditions. Selected configurations were compared with results obtained using MCNP to assess consistency in particle transport and dose estimation. The analysis examines how shielding thickness and material composition affect primary particle attenuation and secondary radiation production, with particular emphasis on neutron contributions generated within regolith and structural materials. Results indicate that integrating favorable topographic placement with optimized structural shielding can significantly reduce overall radiation exposure while revealing trade-offs associated with secondary particle generation, and these findings provide quantitative guidance for radiation risk mitigation and habitat design in future long-duration lunar missions.